April 2, 1968 TSENG W. LIAO 3,376,458

SPARK GAP DEVICE

Filed Nov. 22, 1965

Fig. 1

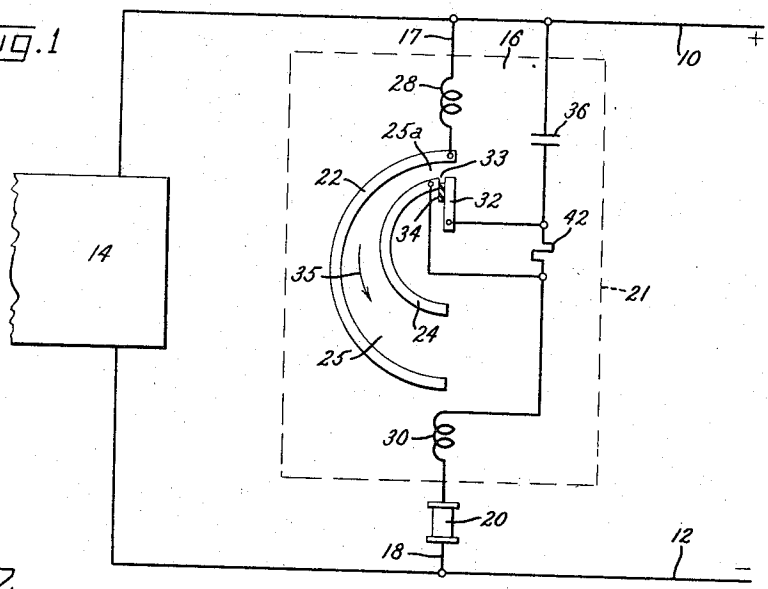


Fig. 2

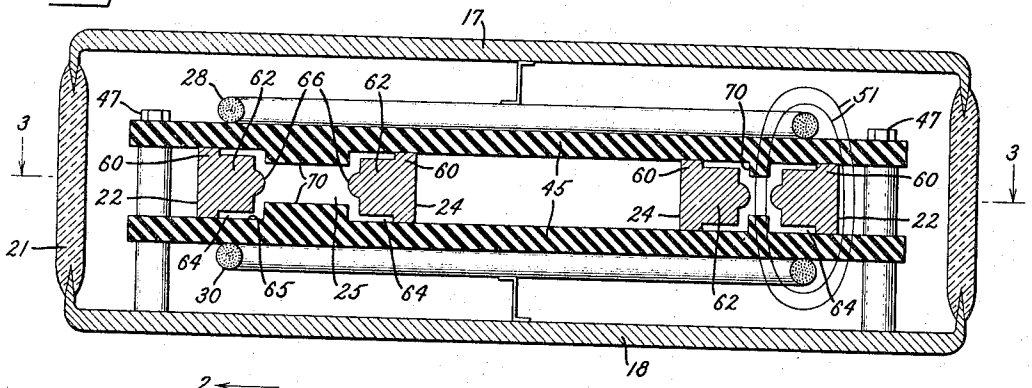
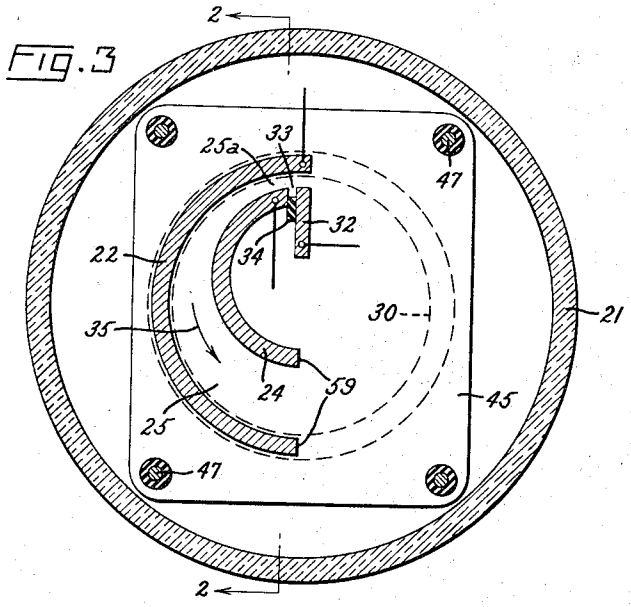


Fig. 3



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SPARK GAP DEVICE

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This invention relates to a spark gap device and more particularly to a spark gap device which comprises a pair of elongated electrodes, or arc runners, along the length of which an arc is driven while disposed between closely-spaced sidewalls of insulating material extending between the arc runners.

In a spark gap of this general type, the sidewalls of insulating material are used for cooling the arc in order to build up a relatively high arc voltage. This arc voltage is used for driving the arcing current toward zero, ultimately extinguishing the arc.

Occasionally, such spark gaps are called upon to dissipate surges having a very high energy content, e.g., thousands of watt-seconds. These high energy surges produce relatively high arcing currents which flow through the spark gap for considerable lengths of time, e.g., tens of milliseconds. These high currents flowing over such long periods vaporize relatively large amounts of the metal of the arc runners. This metal vapor, which is projected in all directions from the arcing region, condenses on the adjacent insulating sidewalls and thus tends to build up a metal coating on these sidewalls.

An object of the present invention is to construct the arc runners in such a manner that these high energy surges can be dissipated without producing a short-circuiting metal coating on the insulating sidewalls between the runners.

Another object is to provide a spark gap device in which the insulating sidewalls can be kept relatively close to the high current arc without being ruined by the deposition of arc-liberated metal particles thereon.

In carrying out the invention in one form, I provide spaced-apart arc runners, each being an elongated bar-like member. Arcs are established between these runners, and means is provided for rapidly driving the arc terminals along the length of the runners. A pair of spaced sidewalls of insulating material extends between the runners at opposite edges thereof generally parallel to the arc. Each arc runner comprises a base and a portion projecting from the base toward the other runner, the base and the projecting portion extending along the length of the runner. At the free end of the projecting portions, arc-terminal-locating means is provided to define an arcing zone where the arc is maintained while on said runners. The projecting portions are spaced from both the sidewalls so that the shortest creepage path between the runners on a sidewall surface extends between said bases alongside and spaced from said projecting portions. The arc runners are so shaped that any straight line path extending between said arcing zone and the portions of said creepage path extending alongside said projecting portions adjacent said bases is intersected by one of said arc runners.

For a better understanding of the invention, reference may be had to the following description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a schematic view of a spark gap device embodying one form of the invention connected to protect a D-C power circuit.

FIG. 2 is a cross-sectional view through a spark gap device of the type schematically depicted in FIG. 1. FIG. 2 is taken along the line 2—2 of FIG. 3 and is enlarged with respect to FIG. 3.

FIG. 3 is a cross sectional view taken along the line 3—3 of FIG. 2.

Referring now to FIG. 1, there is shown a D-C circuit comprising a positive bus **10**, a negative bus **12**, and semiconductor rectifier equipment **14** connected to the buses for supplying D-C power thereto. For various reasons, voltage surges may appear on the buses **10**, **12** that could damage the semiconductor equipment **14** unless suitable protection is provided.

For protecting the equipment **14** from such voltage surges, a surge arrestor, schematically shown at **16** is provided. This surge arrestor has one terminal **17** connected to the positive bus **10** and its opposite terminal **18** connected to the negative bus **12**, preferably through a resistor **20**. The resistor **20** is a nonlinear resistor, preferably made of a material having a negative resistance-current characteristic, such as the material sold by General Electric Company under the trademark Thyrite.

The illustrated arrestor **16** corresponds, in many respects, to the arrestor shown and claimed in application S.N. 298,942—Lee and Liao, filed July 31, 1963, now U.S. Patent No. 3,309,555, and assigned to the assignee of the present invention. It will therefore be described in the present application only to the extent believed necessary to convey an understanding of the present invention. This arrestor **16** comprises a sealed envelope **21** containing an arc-extinguishing gas, preferably one consisting essentially of hydrogen. Disposed within the envelope is a pair of spaced-apart electrodes, or arc runners, **22** and **24** defining a gap **25** therebetween across which arcs are adapted to be established. The arc runners are elongated bar-like members and are preferably of a generally semicircular configuration, with one runner **22** disposed about the other runner **24**. The centers of curvature of the two runners are offset with respect to each other so that the gap **25** is relatively short in length at one end of the runners and gradually increases in length as the other end is approached via a circumferential path extending along the length of the runners. The portion **25***a* of the gap where the runners are closest together is referred to hereinafter as the arc-initiation region, and the remainder of the gap is referred to as the arc-running region.

Connected in series with the runners **22** and **24** are two arc-propelling coils **28** and **30**, one between the terminal **17** and runner **22** and the other between the terminal **18** and runner **24**. The coils are used to create a magnetic field for propelling the arc established between the runners **22** and **24**, as will soon be explained.

For initiating an arc between the runners **22** and **24**, a trigger electrode **32** is provided adjacent the arc-initiating portion of the runner **24**. This trigger electrode **32** is separated from the runner **24** by means of a strip of high dielectric constant insulating material **34**, preferably of barium titanate. When a surge voltage of a predetermined minimum amplitude is applied between the trigger electrode **32** and runner **24**, a spark will jump across the gap **33** between the trigger electrode and runner **24**. The positive ions produced by the spark distort the electric field between the two runners **22** and **24**, reducing the breakdown voltage between the runners **22** and **24** to a value below the applied voltage between the runners. This results in an arc between the two runners **22** and **24** in their arc-initiation regions. The current that flows through the arc also flows through the arc-propelling coils **28** and **30**, and this produces a magnetic field that drives the arc in the direction of the arrow **35** of FIG. 1, as will soon appear more clearly.

For applying surge voltages to the trigger electrode **32** when they appear across the buses **10**, **12**, the trigger electrode **32** is connected to the bus **10** through a capacitor **36**. Under normal or steady state conditions, the trigger electrode **32** will be essentially isolated from the bus **10** by the capacitor **36**. But when surge voltage

appears on bus **10**, the capacitor presents no significant impedance, and most of the surge voltage will appear across the trigger gap **33** between the trigger electrode **32** and runner **24**. The trigger gap **33** has a spark-over voltage that is set at such a value that it will spark over before the surge voltage reaches a damaging magnitude. This spark-over voltage is typically set at about 200% of the normal voltage between the buses **10** and **12**.

A resistor **42** having a low resistance in comparison to the leakage resistance of the capacitor **36** is connected between the trigger electrode **32** and runner **24** to maintain the trigger electrode **32** and runner **24** at substantially the same potential under steady state conditions. Such isolation of the trigger gap from steady state voltage prevents its degradation and possible false sparkovers.

Referring to FIG. 2, it will be noted that the runners **22** and **24** are mounted between two insulating plates **45** that act as sidewalls for the arcing gap **25** between the electrodes. These plates **45** are substantially imperforate in the region of the arcing gap **25** and extend generally parallel to the longitudinal axis of any arc between the runners **22** and **24**. These insulating plates **45** are made of a material that emits very little gas when exposed to an arc, for example, aluminum silicate. The plates **45** are clamped against opposite edges of the runners **22** and **24** by suitable fastening means such as the insulating bolts **47** located at spaced-apart locations around the outer periphery of plate **45**.

The coils **28** and **30** for creating the arc-propelling magnetic field are mounted on the outer sides of the insulating plates **45**. Each of these coils is preferably of a circular configuration as viewed in FIG. 3, and half of the circumference of each coil is disposed approximately in alignment with the semicircular outer runner **22**. The coils are connected in the circuit in such a manner that when current flows through the arrestor, it flows through each of the coils in the same angular direction. Thus, a magnetic field **51** surrounding the two coils **28** and **30** and having the general configuration depicted in FIG. 2 is developed. At all points along the length of the outer runner **22**, this magnetic field **51** extends across the arcing gap **25** in a direction generally perpendicular to the longitudinal axis of any arc between the runners **22** and **24**. As is known, a magnetic field applied transverse to an arc will coact with the local magnetic field around the arc to drive the arc in a direction transverse to the longitudinal axis of the arc and transverse to the direction of the applied magnetic field. The polarity of the applied magnetic field is selected so that the arc-propelling force is in the direction of arrow **35** in FIGS. 1 and 3. Thus, when an arc is established at the arc-initiating region **25***a*, it is driven along the runners **22** and **24** in the direction of arrow **35** to the opposite end of the runners.

The motion of the arc in the direction of arrow **35** of FIG. 3 progressively lengthens the arc due to the progressively increasing length of the arcing gap **25**. This progressive lengthening of the arc produces a progressive increase in the arc voltage, which progressively reduces the arcing current. When the arc voltage exceeds the voltage applied by the system to the main gap, the arcing current will rapidly approach zero. If the energy of the voltage surge that initiated the arc has then been dissipated in the arrestor, the arc will be extinguished and no further breakdown of the gap **25** will occur, thus enabling the system to be restored to normal operation. It will be apparent that the highest arc voltage is developed when the arc reaches the end **59** of the runners **22**, **24** where the gap length is a maximum.

If the voltage surge is a high energy surge, only a portion of the surge energy will have been dissipated by the time the arc reaches its maximum arc-voltage position at the end **59** of the runners. The remaining surge energy will produce another abrupt voltage rise

that will cause the main gap to spark over in the arc-initiation region **25***a*, thus establishing another arc between the runners in the arc-initiation region **25***a*. The first arc may or may not have been completely extinguished at the instant that the second arc is established, but upon establishment of the second arc, the first arc vanishes. The second arc, like its predecessor, is driven in the direction of arrow **35** into a maximum arc-voltage position at the end **59** of the runners thereby increasing the arc voltage and driving the arc current rapidly toward zero. Just before or as soon as the current reaches zero, the surge voltage resulting from the remaining surge energy initiates a third arc in the arc-initiation region **25***a*. The second arc vanishes, and the third arc is handled in the same manner as its predecessor. This sequence of events is repeated over and over again until the surge energy is finally completely dissipated. When this complete dissipation occurs, the maximum arc voltage developed when the arc is in its position at the end of the runners is insufficient to cause a breakdown at the arc-initiation region **25***a*, and hence the gap acts thereafter to prevent further current flow.

There are a number of factors controlling the amount of arc voltage that is developed between the arc runners at any given instant. One of these is the spacing between the arc runners, which determines the length of the arc at any given instant. Another is the spacing between the insulating sidewalls **45**. By keeping this spacing relatively small, the sidewalls can produce effective cooling of the arc, and this likewise assists in building up the desired high arc voltage.

The arcs produced by high energy surges can vaporize relatively large amounts of the metal of the arc runners. This metal vapor is projected outwardly from the arc in substantially straight line paths that extend away from the arc in all directions. This metal vapor will condense on any cool surface that it contacts, thereby depositing metal on the surface. Since my gap device comprises insulating side walls **45** located in close proximity to the arc, it will be apparent that a metal coating tends to build up on the sidewalls after exposure to the arcs accompanying high energy surges.

As previously stated, an object of my invention is to prevent such arcs from developing on the sidewalls **45** a metal coating that could form a short circuiting path extending between the runners **22**, **24**.

In the illustrated form of my invention, I rely upon several features to accomplish this result. One of these features is that I form my arc runners of the transverse cross-sectional shape shown in FIG. 2. More specifically, each of the elongated bar-like runners comprises a base portion **60** extending along the complete length of the runner and clamped between the two sidewalls **45**. Projecting from each of these bases toward the other of the runners is a projecting portion **62**, which also extends along the complete length of the runner. The projecting portions **62** of the two runners are spaced from both of the sidewalls, as shown at **64**, so that the shortest creepage path between the runners on a sidewall surface **65** extends between the bases **60** alongside the projecting portions **62** but spaced therefrom.

Projecting slightly from the free ends of the two projecting portions **62** are arc-terminal-locating bosses **66** defining an arcing zone therebetween. Each of these bosses **66** extends along substantially the complete length of its associated runner and is generally centrally-located with respect to the height of the runner as viewed in FIG. 2. For reasons which will soon be explained, the arc roots of any arc present between the runners remain attached to the bosses **66**. Thus, the arcing zone is always located between the central bosses **66**, spaced laterally inward from the horizontally-disposed sides of projecting portions **62** of the runners.

Adjacent the bases **60** of the two arc runners there are sidewall regions that are shielded from the metal vapors

that are projected outwardly from the above-described arcing zone. In this connection, any straight line path extending from the arcing zone to the shielded sidewall portions will intersect an arc runner before it reaches the shielded sidewall portion. As a result, metal particles following these straight line paths will be intercepted and condensed by the arc runners before they can reach the shielded regions of the sidewalls. As a result, these shielded regions of the sidewalls adjacent bases **60** will remain substantially free of metal deposits. This has been confirmed by actual tests in which the spark gap was subjected to many repeated operations under high energy surge conditions. These operations produced a metal deposit on the sidewall regions aligned with the arcing zone but none adjacent the bases **60**.

To assure that there will be no straight line paths from the arcing zone to the shielded sidewall portions, it is important that the arc roots be maintained on the bosses **66** so that the arcing zone is confined to a location between the bosses. Since the minimum gap length is present between the bosses **66**, there is a definite tendency for the arc roots to remain attached to these bosses. But opposing this tendency of the arc to remain on the bosses **66** is the buoyancy of the hot arc, which can produce a significant upward force on the arc, assuming the arc extends generally horizontally as shown. I prevent the arc from moving upwardly by driving it at high speed along the length of runners **22**, **24**, thereby moving it through any given location before any substantial upward forces can develop on the arc due to buoyancy or other factors. An added feature tending to maintain the arc roots on the bosses **66** are the projections **70** on the sidewalls. These projections **70** extend into the space between the arc runners and help to prevent any arc between the runners from moving laterally off the bosses **66**. It should be noted that sidewall projections **70** progressively widen as the gap **25** lengthens. As a result, portions of the sidewall projection **70** are always located in proximity to the arc runners, so as to restrict the passage between gap **25** and the shielded sidewall portions adjacent bases **60**. In addition, the proximity of the sidewall projection **70** to the arc runners renders the projections more effective in confining the arc, even in its terminal regions, to a position where it is prevented from spraying metal vapor on the shielded portions of the sidewalls.

The sidewall projection **70** also served to locate insulating material in close proximity to the arc, thereby insulating material in close proximity to the arc, thereby accelerating the arc-cooling process. But despite this proximity of the sidewalls to the arc, the sidewall regions adjacent bases **60** remain shielded from metal vapor condensate.

Although I have shown my invention embodied in a triggered spark gap device, it is to be understood that, in its broader aspect, it can also be embodied in a spark gap device that has no trigger.

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects; and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A spark gap device comprising:

(a) a pair of spaced-apart metallic arc runners, each being an elongated bar-like member,

(b) means for establishing an electric arc across the gap between said runners with one arc terminal on one runner and the other arc terminal on the other runner,

(c) means for rapidly driving said arc terminals along the length of their respective runners,

(d) a pair of sidewalls of insulating material extending between said runners at opposite edges thereof and generally parallel to said arc,

(e) each of said arc runners comprising a base and a portion projecting from said base toward the other of said arc runners, said base and said projecting portion both extending along the length of said runner,

(f) arc-terminal-locating means defining an arcing zone at the free end of said projecting portions where the arc is maintained while on said runners,

(g) said projecting portions being spaced from both of said sidewalls so that the shortest creepage path between said arc runners on a sidewall surface extends between said bases alongside and spaced from said projecting portions,

(h) said arc runners being so shaped that any straight line path extending between said arcing zone and the portions of said creepage path extending alongside said projecting portions adjacent said bases is intersected by one of said arc runners.

2. The spark gap device of claim **1** in which said arcing zone is confined to a region that is located laterally inwardly from the lateral sides of said projecting portions of the arc runner that extend alongside said sidewalls.

3. The spark gap device of claim **1** in which said arc-terminal-locating means comprises a pair of bosses on said arc runners at the free ends of said projecting portions, said bosses extending along the length of the arc runners and being located laterally inward from the lateral sides of said projecting portions of the arc runners.

4. The spark gap device of claim **1** in which said sidewalls have projections of insulating material thereon extending into the space between said arc runners, said sidewall projections having portions located in close proximity to said arc runners for confining the terminal portions of the arc to a position where there are no uninterrupted straight line paths between the arc and the shielded sidewall portions adjacent the bases of the arc runners.

5. The spark gap device of claim **1** in which:

(a) arcs between said runners are initiated at a predetermined location on said runners,

(b) the gap between the arc runners increases in length at locations progressively further away from said arc-initiation location,

(c) said sidewalls have insulating projections extending into the space between said runners, said sidewall projections extending along the length of said runners and having an effective width that increases as the gap lengthens, thereby maintaining portions of said sidewall projections in close proximity to said arc runners along the arc-runner length.

6. The spark gap device of claim **1** in which said arc runners are located in a generally horizontal plane whereby said arc extends generally horizontally.

References Cited

UNITED STATES PATENTS

3,287,588	11/1966	Lee et al.	315—36 X
3,309,575	3/1967	Thomas Lee et al.	313—325 X

FOREIGN PATENTS

1,310,009	10/1962	France.

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